# Development of a Helical Path Tree Climbing Snake Robot

***Design Presentation II***


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# Problem Definition

- Unstable trees may fall at any moment
- Fallen trees cause over $1 billion worth of damage annually
- Removing tall trees should be done by professionals
  - Requires specific skills and precision
  - 200 tree-related fatal injuries every year

# Tree Removal Services

- Removing Process:
  - De-limbing on the way up
  - Cutting small segments on way down
  - Cut at base once at controllable height
- Price ranges from $150-$2,000
  - Complexity of job
  - Height of tree
- Focus on pine trees
  - Average Diameter: ~2 ft
  - Height: Up to 100 ft
  - Shape: Round and straight

# Project Goal Statement

## Original Scope:

- To climb a tree in a helical manner and cut it down via the method of 'topping'.

## Revised Scope:

- To climb a branchless tree, in a helical manner, carrying a payload for future iterations.

## Goal Statement:

- Build a remotely operated snake-like robot that will safely climb trees.

# Project Goal Statement

Objectives:

- Ascend and descend a tree while satisfying the following:
  - Tree diameter of at least 10 in
  - Climb in a helical (spiral) path
  - Ascend at a speed of at least 1 ft/min
  - Hold up at least 10 lb
  - Attach camera to provide feedback

# Motor Selection - old motor

| | Clamping | Helix |
|---|---|---|
| Calculated Torque | $20\ lbf \cdot ft$ | $20\ lbf \cdot ft$ |
| Motor stall torque | $0.74\ lbf \cdot ft$ | $0.74\ lbf \cdot ft$ |
| Motor max speed | $23\ rpm$ | $23\ rpm$ |

Motor Selected:

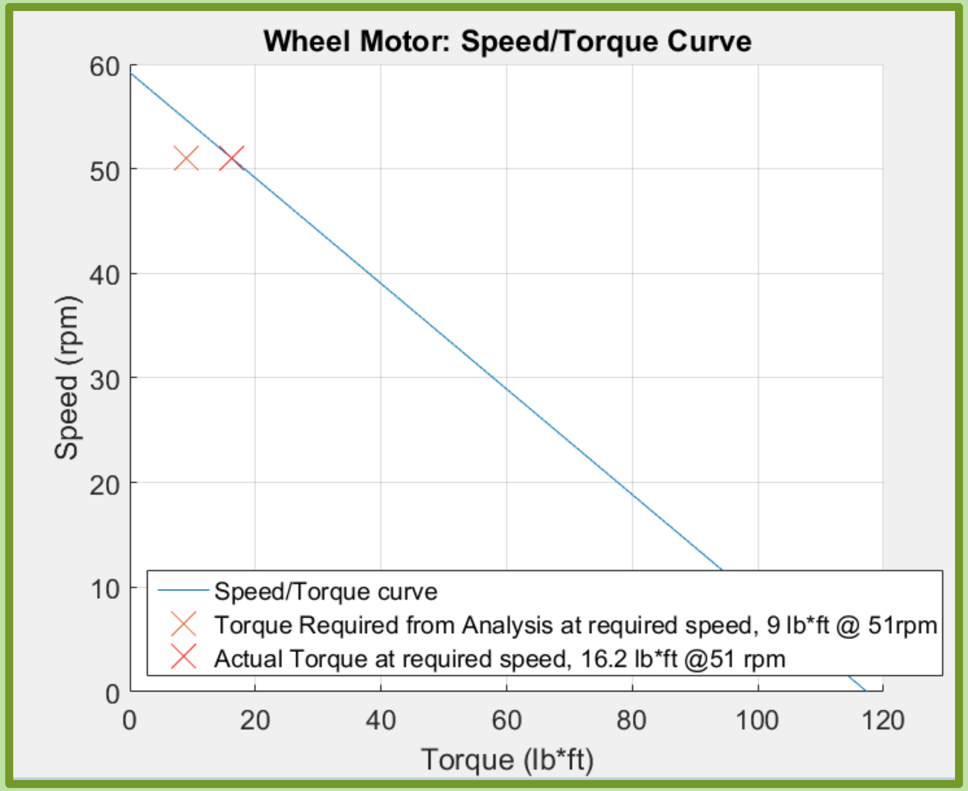
- DC motor
- 12 V
- 90 mA
- Gear Ratio- 100:1

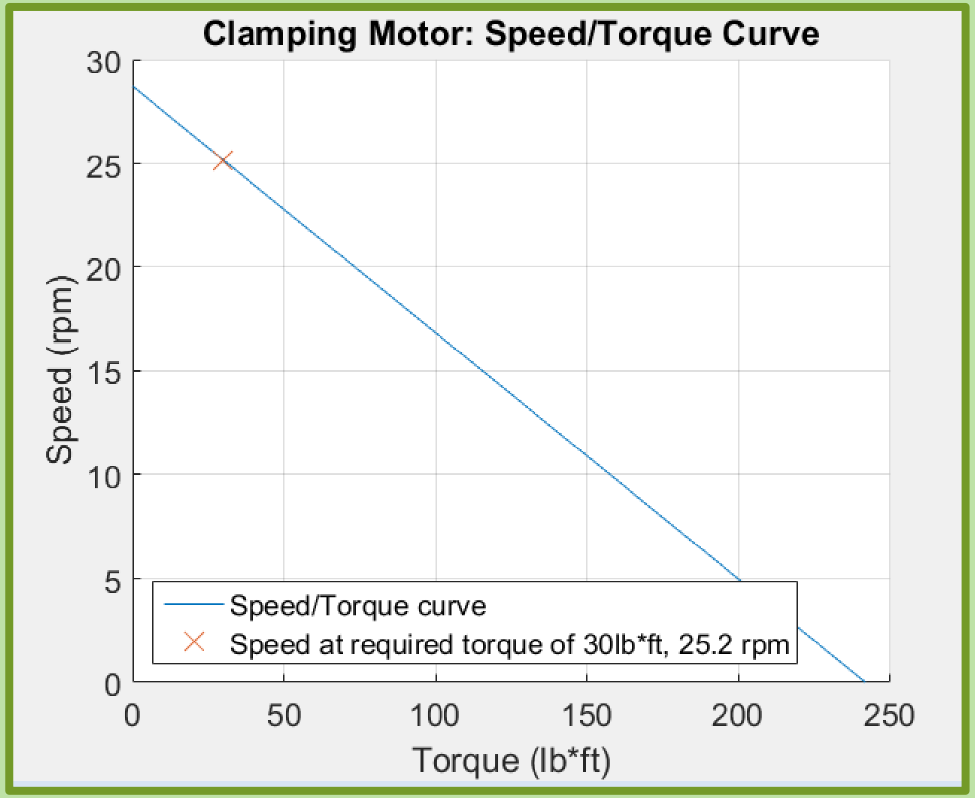
# Motor Selection - New Motor

| Element | Motor (driving) | Gearbox (driving) | Total |
| --- | --- | --- | --- |
| Speed | 19,300rpm | 326:1 | 59.2 rpm |
| Torque (stall) | 0.3602 lb-ft | 326:1 | 117.4 lb-ft |
| Weight | 7.7oz | 11.4oz | 1.194 lbs |

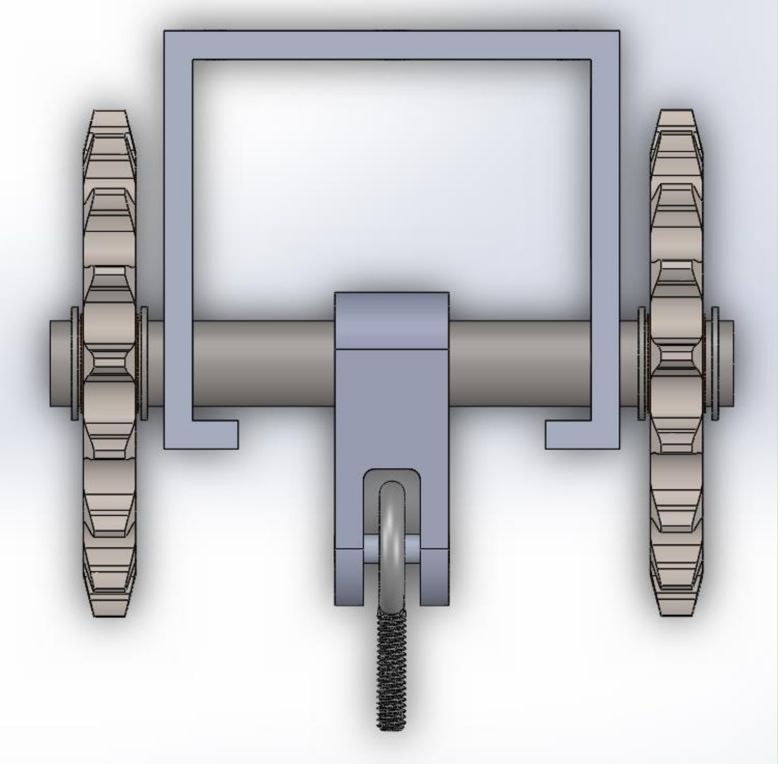
| Element | Motor (clamping) | Gearbox (clamping) | Total |
| --- | --- | --- | --- |
| Speed | 19,300rpm | 672:1 | 28.7 rpm |
| Torque (stall) | 0.3602 lb-ft | 672:1 | 242.1 lb-ft |
| Weight | 7.7oz | 11.4oz | 1.194 lbs |

# Torque-Speed Curve for Motor

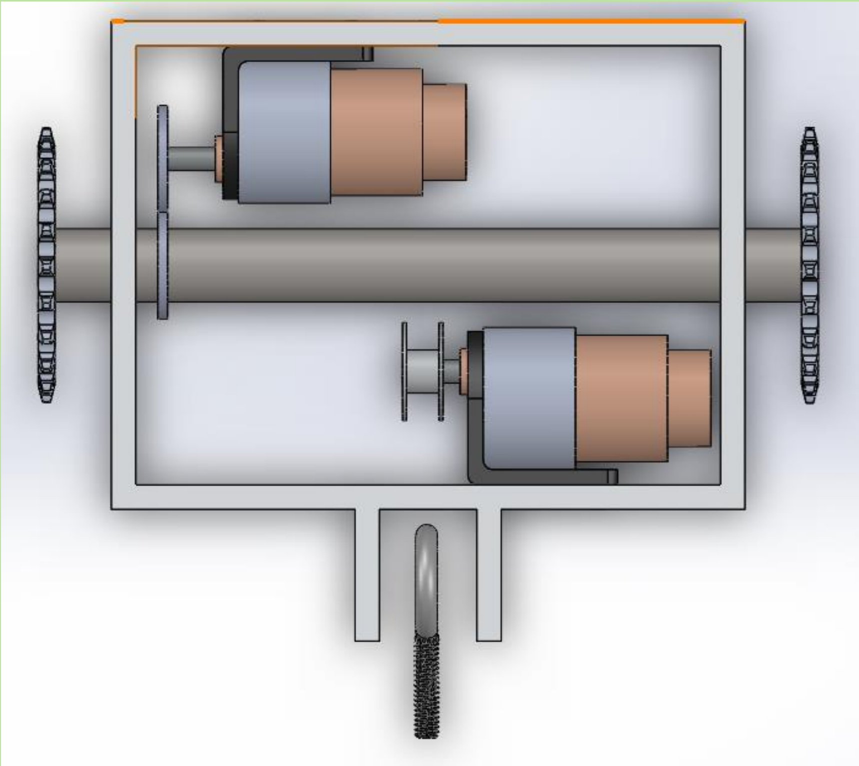


# Design Alteration - Previous Design

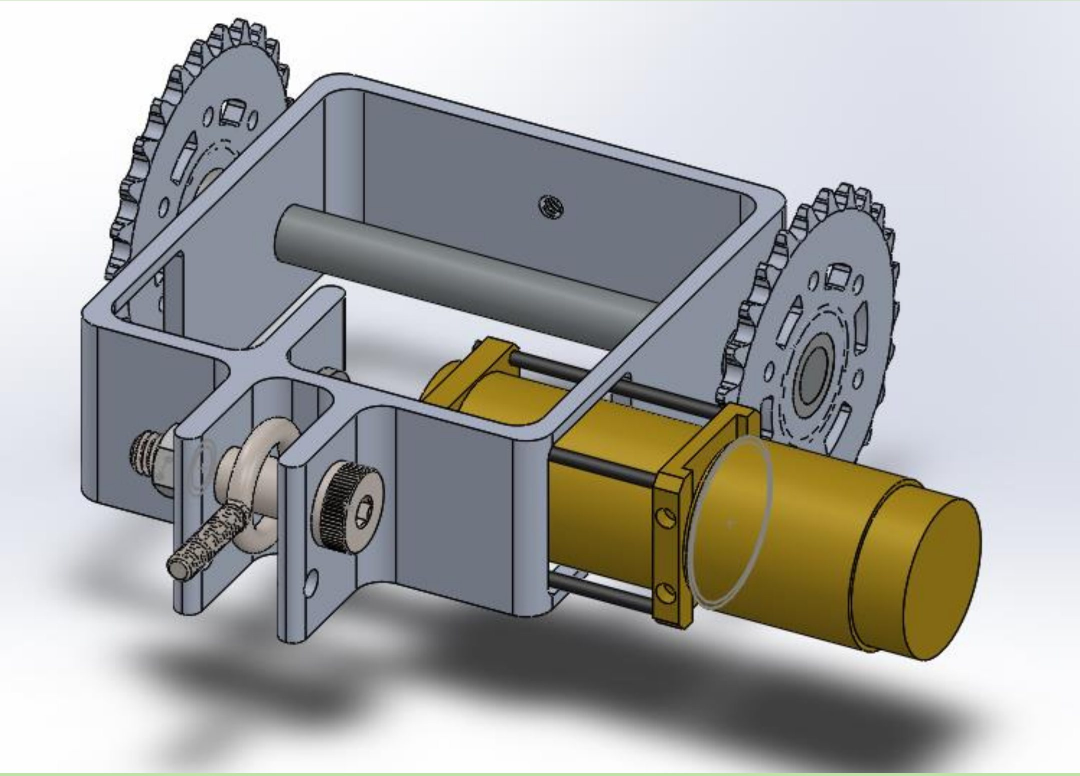


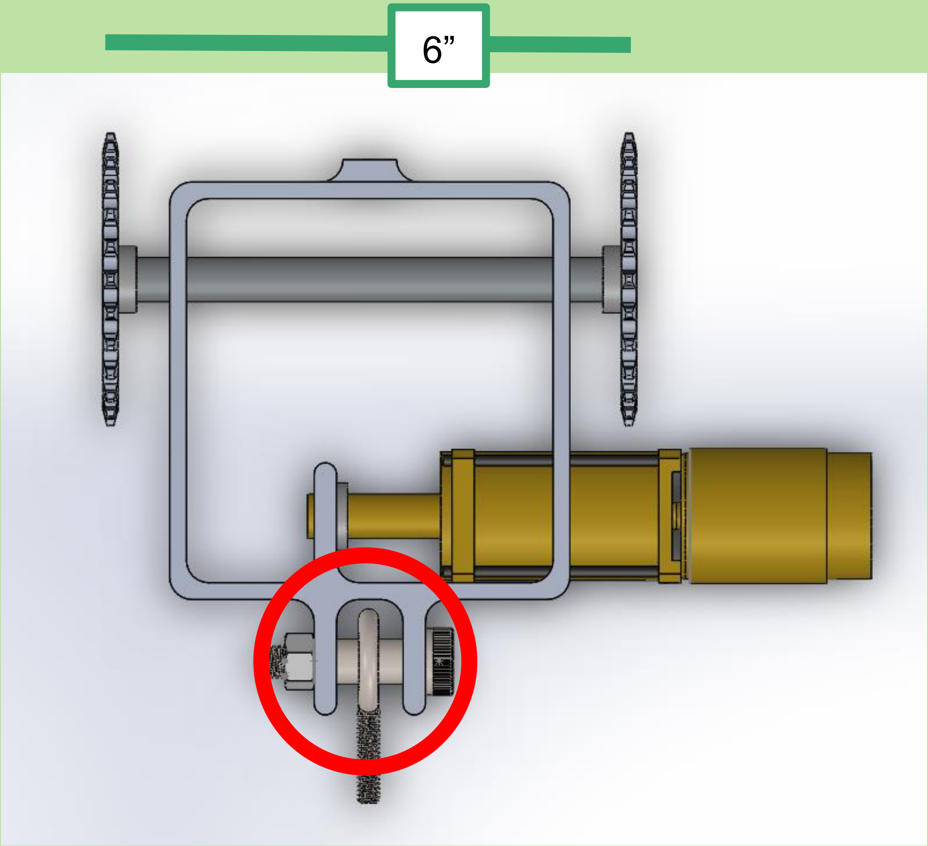
Body Module



Motor Module

# Design Alteration - Improved Design



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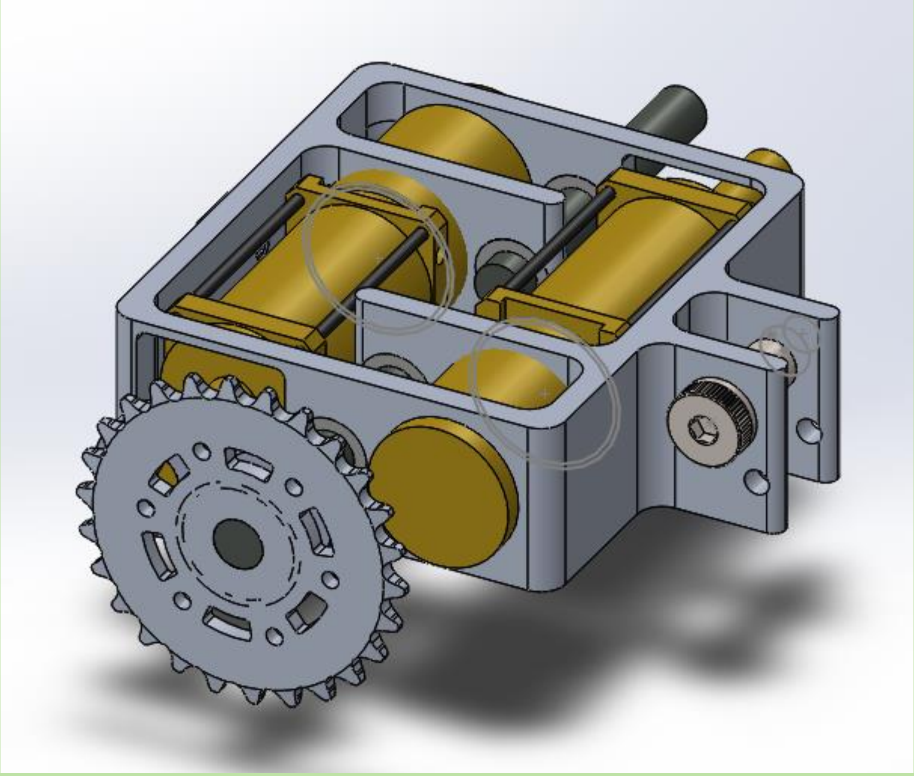
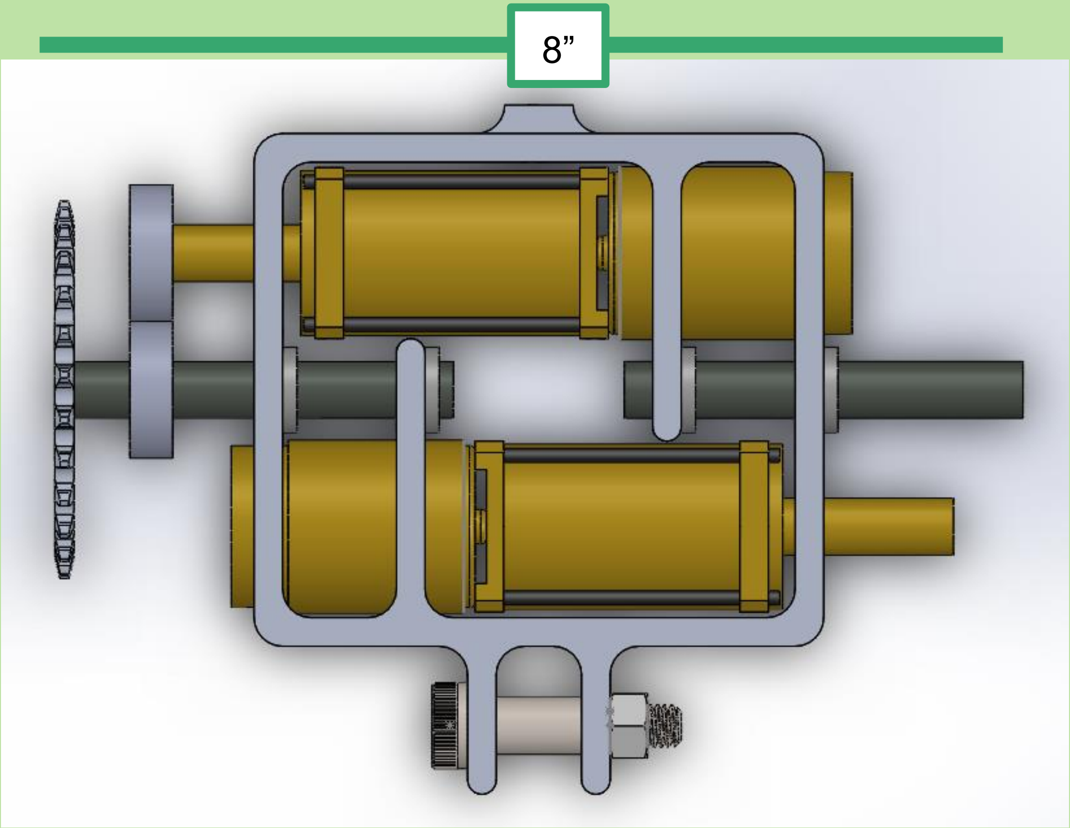
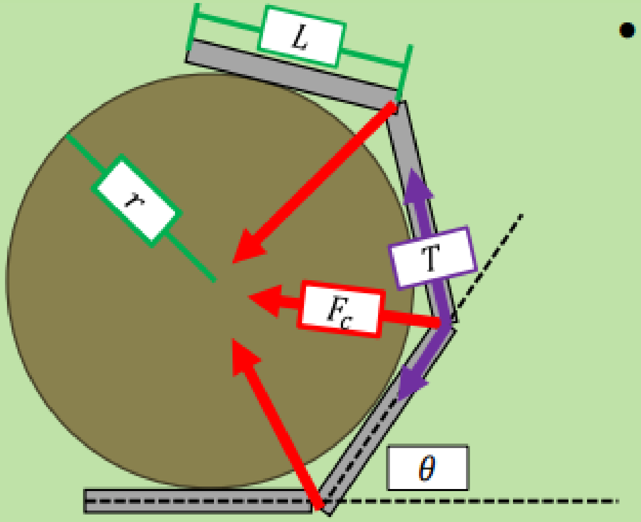
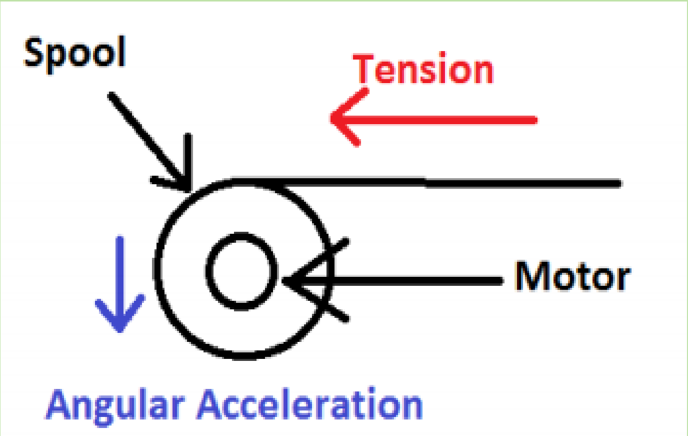
# Design Alteration - Improved Design





# How Our Design Works - Clamping




- Assumptions:
  - Tension ($T$) is constant
  - Module-to-module angle change ($\theta$) is constant
  - Clamping is independent of helix
  - No losses due to friction

**Final torque needed for clamping ≈ $20\ lbf \cdot ft$**

$$\theta = 2\tan^{-1}\left(\frac{L}{2r}\right)$$

$\theta$ is the module-to-module angle
$L$ is the length of the module
$r$ is the radius of the tree

$$F_c = T\sqrt{2 - 2cos\theta}$$

$F_c$ is the clamping
$T$ is the tension

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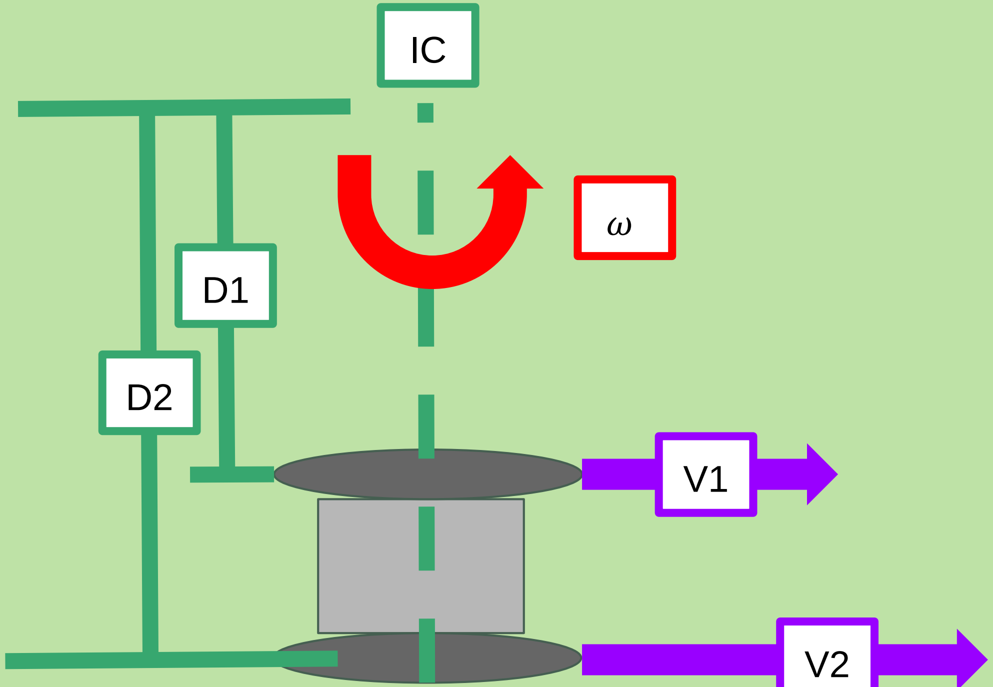
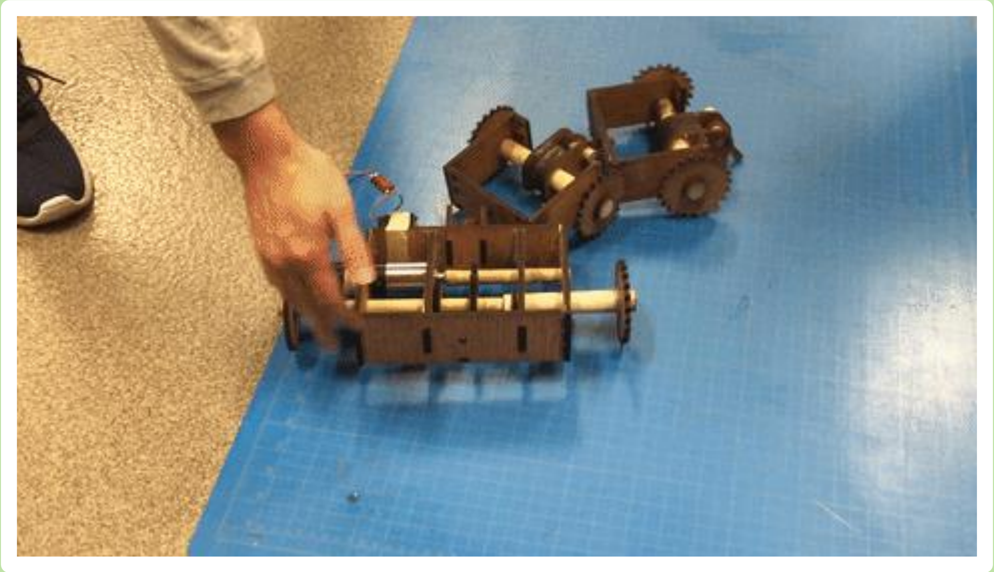
# How Our Design Works - Differential

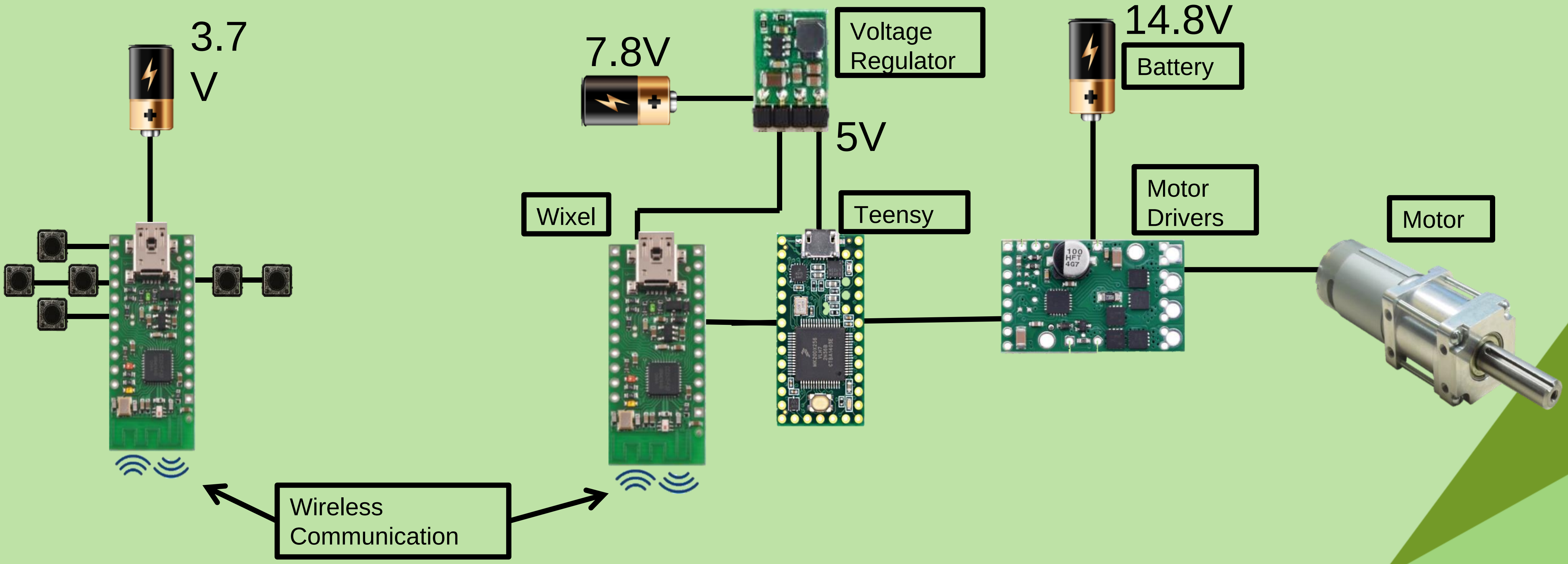


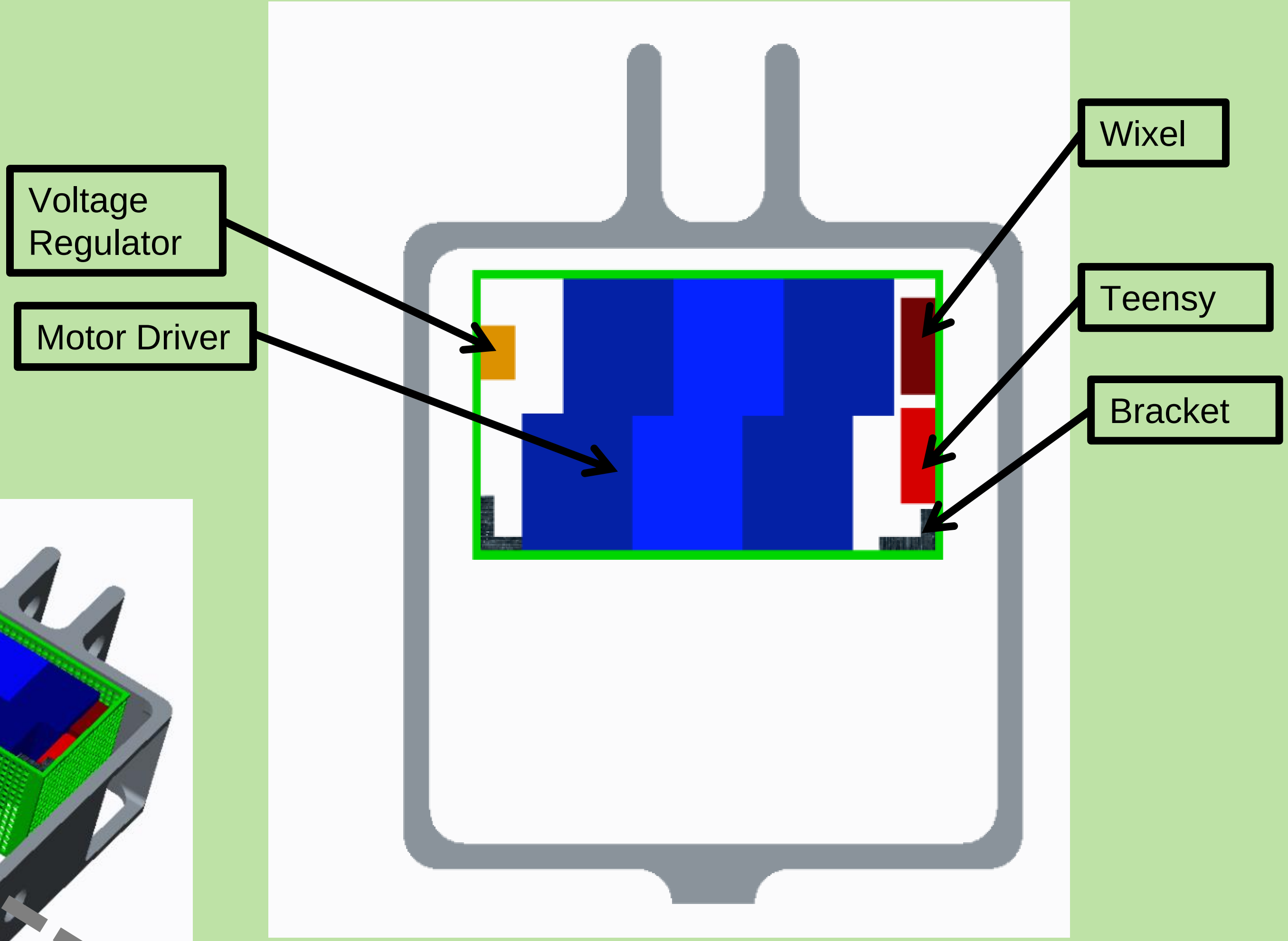
$$\omega = \frac{V_2 - V_1}{h}$$

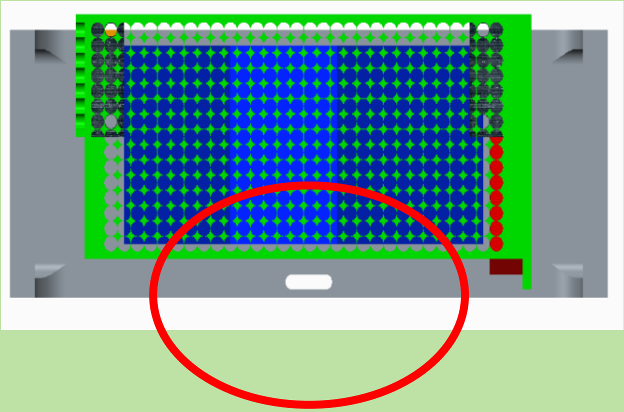
# Proof of Concept - Differential

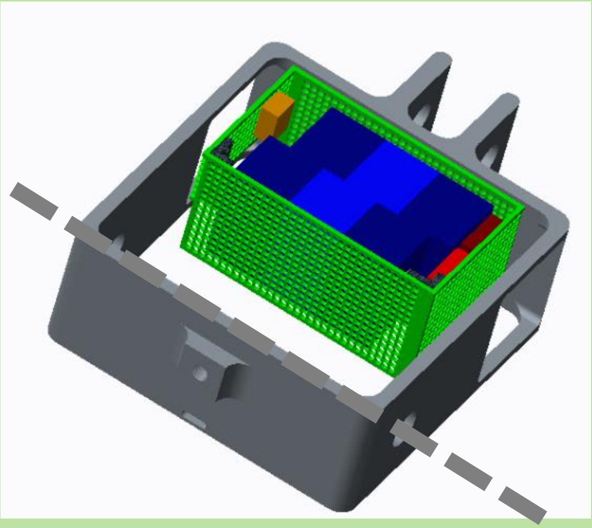
# Electronics - board and components



# Electronics - board and components





# Electronics - Wireless Camera

- Backup Camera and Monitor
  - 4.3” Monitor
  - Rated Voltage: 12 V
- Wireless Color Video Transmitter and Receiver
  - Signal Range: 15-20 m

# Battery Selection

| Component | Max Current Draw (A) | Battery Capacity (mAh) | Runtime (Capacity/Current) |
|---|---|---|---|
| Motor | 12.0 | 2250 | 11min |
| Voltage Regulator | 0.600 | 1000 | 1.6hr |
| Wixel | 0.060 | 260 | 4.3hr |
| Camera | 0.350 | 1100 | 3.1hr |
| Monitor | 0.900 | 1100 | 1.2hr |

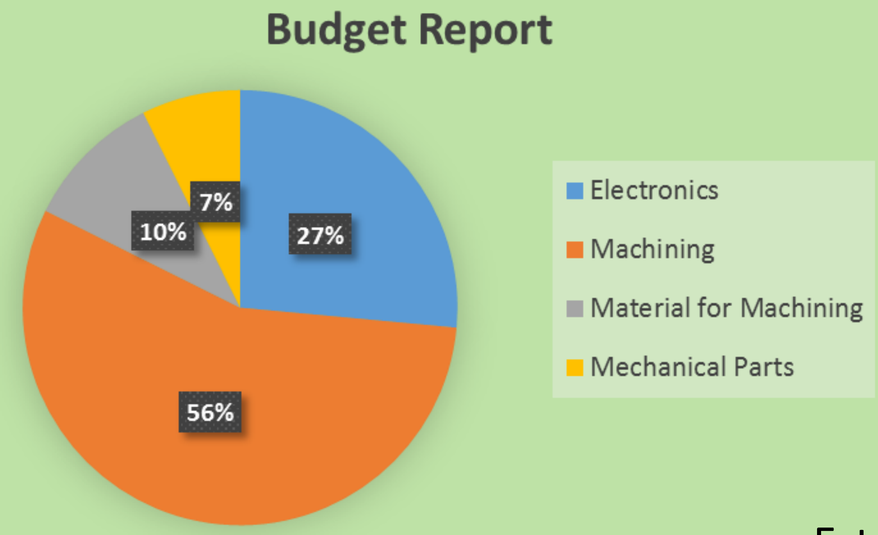
# Battery Selection

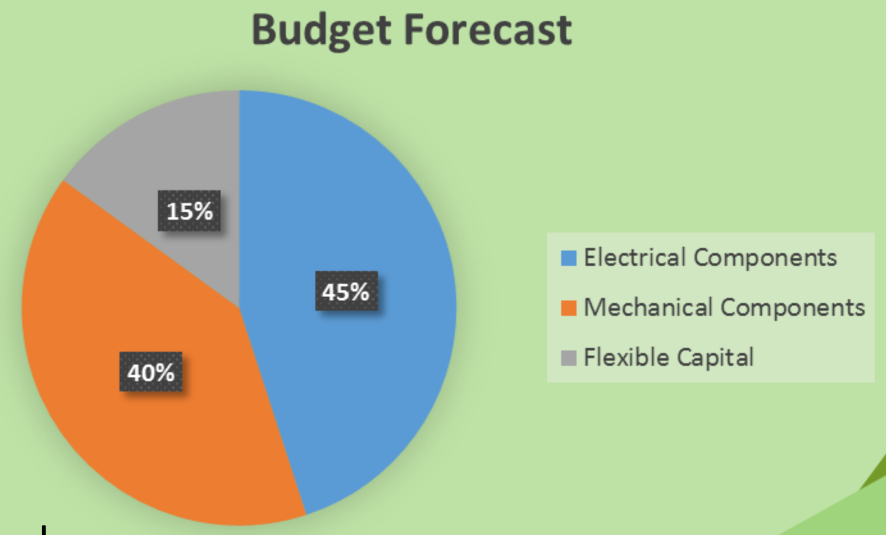
- Inner dimensions of car: 110x83x38mm
- Selection for prototype

| Specs | Battery A | Battery B |
|---|---|---|
| Capacity (mAh) | 2250 | 5000 |
| Expected Runtime (min) | 11 | 24 |
| Size (mm) | 104X35x34 | 143X51X33 |
| Weight (g) | 243 | 460 |
| Warehouse Location | US | Hong Kong |

# New Cost Estimate

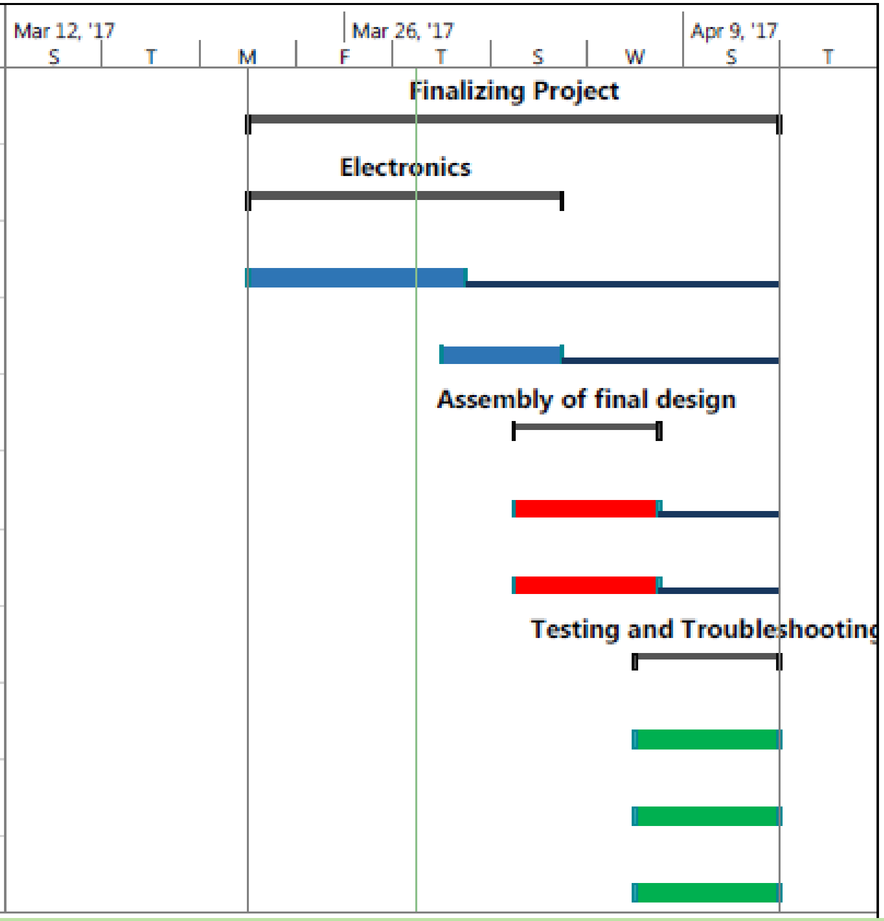
| Component | Cost |
|---|---|
| Electronics | 900 |
| Machining | 1900+350 |
| Mechanical Parts | 250 |
| Total | 3400 |



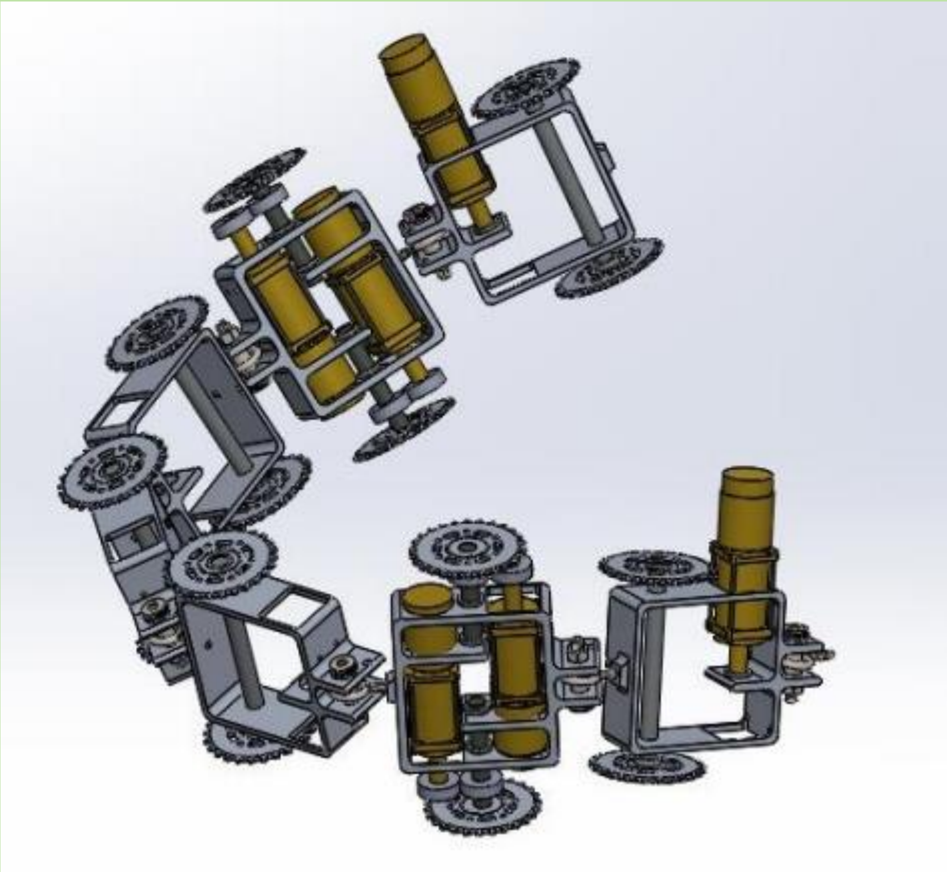
# Future Plans

| Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|
| **Finalizing Project** | **16 days** | **Wed 3/22/17** | **Wed 4/12/17** | |
| **Electronics** | **9 days** | **Wed 3/22/17** | **Mon 4/3/17** | |
| Implement wireless communication | 7 days | Wed 3/22/17 | Thu 3/30/17 | |
| Test motor response to wireless | 3 days | Thu 3/30/17 | Mon 4/3/17 | |
| **Assembly of final design** | **5 days** | **Sun 4/2/17** | **Fri 4/7/17** | |
| Mechanical components | 6 days | Sun 4/2/17 | Fri 4/7/17 | |
| Electrical components | 6 days | Sun 4/2/17 | Fri 4/7/17 | |
| **Testing and Troubleshooting** | **4 days** | **Fri 4/7/17** | **Wed 4/12/17** | |
| Clamping | 4 days | Fri 4/7/17 | Wed 4/12/17 | |
| Motion | 4 days | Fri 4/7/17 | Wed 4/12/17 | |
| Combined System | 4 days | Fri 4/7/17 | Wed 4/12/17 | |



# Summary

- We reworked the motor selection
    - This lead to a rework in design
- Finalized purchases for materials and electronics
    - We are waiting for parts to arrive
- Waiting on machine shop for parts and assembly
    - Waiting for assembly to begin testing
- Preparing to test basic functions as well as payload positioning



# References


- P. Polchankajorn and T. Maneewarn, “Development of a helical climbing modular snake robot,” in 2011 IEEE International Conference on Robotics and Automation, May 2011, pp. 197–202.
- Snake Robot: http://farm4.staticflickr.com/3779/9313104039_867fafb326.jpg
- Pine tree: https://img1.cgtrader.com/items/152956/f9362d2d16/pine-tree-collection-3d-model-obj-3ds-fbx-3dm-dwg.jpg
- http://www.dot.state.mn.us/bridge/pdf/insp/USFS-TimberBridgeManual/em7700_8_chapter03.pdf

# QUESTIONS?

# Appendix A - Tree Curvature